

Final Report

Project Title: Hot Billet Surface Qualifier

Award Number: DE-FG36-05GO15160

Project Period: August 1, 2005 to March 31, 2007

Date of Report: April 01, 2007

Recipient: OG Technologies, Inc.
4300 Varsity Drive, Suite C
Ann Arbor, MI 48108

Contact: Tzyy-Shuh Chang, Ph.D. (PI)
734-973-7500
Chang@ogtechnologies.com

Terence C. Liddy (President of the Recipient)
734-973-7500
Liddy@ogtechnologies.com

Project Team: DOE HQ Program Manager: Lisa Barnett
DOE Field Project Officer: Christine Carter
Deborah Weems

EXECUTIVE SUMMARY

OG Technologies, Inc. (OGT), developed a prototype of a **Hot Billet Surface Qualifier** (“**Qualifier**”) based on OGT’s patented HotEye™ technology and other proprietary imaging and computing technologies. The Qualifier demonstrated its ability of imaging the cast billets *in line* with high definition pictures, pictures capable of supporting the detection of surface anomalies on the billets. The detection will add the ability to simplify the subsequent process and to correct the surface quality issues in a much more timely and efficient manner. This is challenging due to the continuous casting environment, in which corrosive water, temperature, vibration, humidity, EMI and other unbearable factors exist. Each installation has the potential of 249,000 MMBTU in energy savings per year. This represents a cost reduction, reduced emissions, reduced water usage and reduced mill scale.

PROJECT DESCRIPTION

1. Original project goals and objectives

OGT, together with its industrial partner, designed, built and tested a prototype of the proposed Qualifier. The goal of this program is to develop and demonstrate a Qualifier prototype that would function in a real world continuous caster.

The scope of work of this project and the associated objectives are delineated as following:

- (1) To build the prototype of the Qualifier.
- (2) To demonstrate the capability of the Qualifier with 10% false positive rate at the end of the project.

In addition to the technical objectives, the scope of work extends to the area of commercialization. OGT expects to achieve with its own resources:

- (a) Establishing a purchase option agreement with the beta-hosting mill.
- (b) Achieving a sale of a Qualifier within 6 months after the project ends, in addition to the sale to beta-hosting mill.

2. Variance from original goals and objectives

The original goals and objectives are held same. Nevertheless, about the “10% false positive rate”, there is still an issue on the “definition” of what is a true detection and what is not. As a result of the newly established ability to image the billets as they are cast, surfaces of these billets are being revealed for the first time. There exist features that even the veterans in the hosting mill could not comment immediately. The verification on the impact of those features to the subsequent rolling processes is difficult in the hosting mill as the mill is practicing direct charge. Although we reviewed some billets by setting them aside, the amount of billets was very limited and not all the features were captured in these billets. OGT could only report the data from the reviewed billets. The results were interesting enough that the host mill would continue the investigation effort.

As a summary of the project execution, OGT conducted the following:

- (1) Built a prototype of the Qualifier and tested in a continuous caster for 11 months.
- (2) Demonstrated the capability of the Qualifier with detection capability.
- (3) Established an agreement with the hosting mill to revise and re-install the Qualifier.
- (4) Received an order for a billet inspection system, currently being installed in a Canadian steel mill.

3. Discussion of work performed, hurdles overcome, findings, results and analysis, etc. (preferably by specific task so that it is easily comparable to the original Statement of Objectives)

Work performed included

- (1) Built a prototype of the Qualifier;

- (2) Tested it in a continuous caster for 11 months;
- (3) Refined the design; and
- (4) Demonstrated the capability of the Qualifier with detection capability.

The work of Building a Prototype (Tasks A and B) went smoothly given the fact that OGT had more control in the schedule and we received good support from the collaborating industrial partner. The hurdle in this phase of work was on the software modification. As hot billets were not imaged prior to this project, we had to “guess” how the various feature would appear in the images. The team worked with the collaborating industrial partner to review the samples (room temperature) and generate similar features on a dummy for software tests.

The Installation of the Prototype (Task C) was completed with issues unexpected. First, the cooling water was not appropriate due to the high back pressure from the draining pipe. A differently cooling water system was piped to resolve this issue. The other issue has to do with the high pressure air quality. While the solids are limited, the oil content in the air is a problem. The oil, over a period of time, could jam the air knives used in the system for water removal, resulting in the requirement of frequent air knife cleaning. Additional measures were tested and implemented to resolve this issue.

Tests (Task D) were full of lessons learned in this project, particularly in the following aspects.

(a) Mill utility supplies

Mill utility supplies were not stable during the test period. The Qualifier prototype experienced fluctuations in electricity and high pressure air. Both OGT and the collaborating industrial partner worked together to address the issues. For instance, the collaborating industrial partner installed, at its own cost, an industrial-grade power stabilizer from Solar. However, the problem was only reduced, not eliminated. Unstable electrical power caused unwanted system interruptions, even with power stabilizers and uninterrupted power supplies. Air supply was another issue. Aside from the fact that the oil carried by the air could jam the air knives, air supply could be reduced or even cut off from time to time. This was due to the volume of the available high-pressure air. When there was not enough air, water in the caster would not only block the view to the billet surface, but also damage the optical windows.

(b) Caster environment

A harsh environment was expected. However, the degree of harshness was not clear until the Qualifier was tested in the caster, given the limited access to a caster during its normal operation (for safety reasons). The amount of water on the billet surface was underestimated, for instance. In addition, the amount of steam or vapor carried in the ambient air was underestimated. The corrosiveness of the environment was further evidenced by the test results. Heavy deposition, on top of the corrosion, was another challenging environmental factor. Access to the Qualifier when in operation was another issue. Planning prior to the design already factored in access for maintenance. However, physical operations yielded several items of “I wish ...” in terms of design changes for better access. These factors, coupled with the utility supply issue, made the system difficult to maintain.

(c) Protection of Electronics

The sensor head of the Qualifier is full of electronics. Through the 11 months of tests, the original design of the electronic protection proved to be effective, keeping all the electronic components fresh and functional.

(d) Protection of Optics

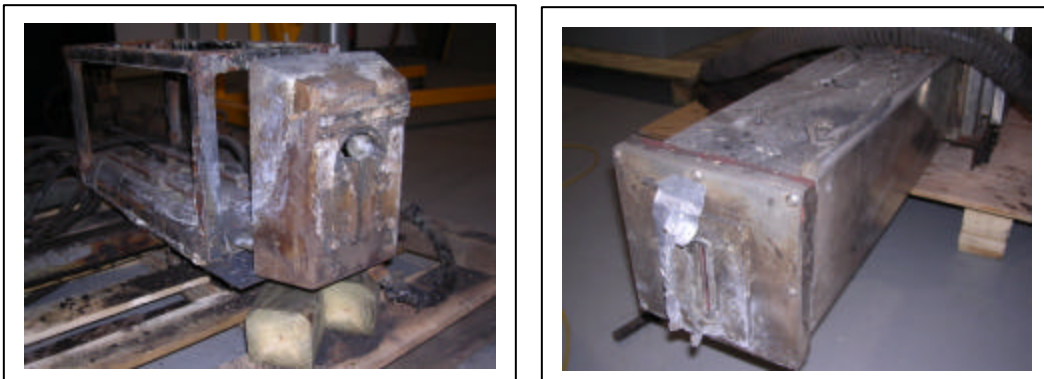
Similar to the protection for the electronics, optics were well protected in the Qualifier, except for the front window, which was exposed to the hot billet and caster water. During the 11 month testing period, the team replaced the front window 3 times. All other optics are still fresh and functional. A new design would be implemented to further safeguard the front window.

(e) Billet Variations

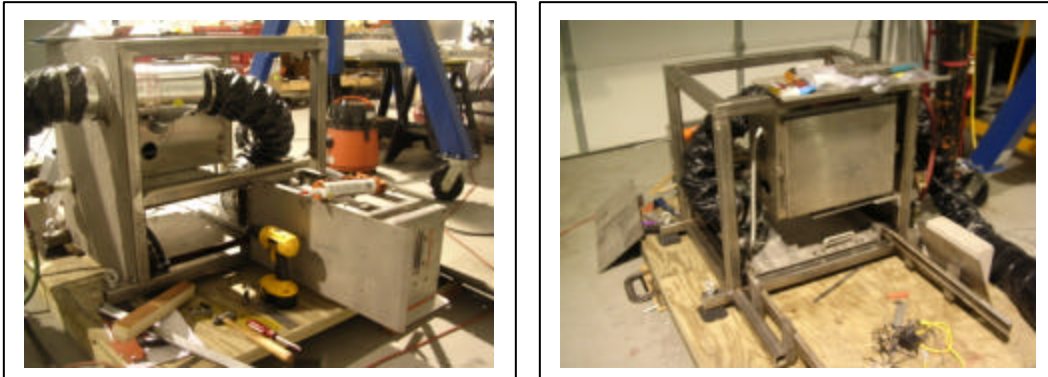
The assumption was that the billet would be “steady” (very small variations) in the caster as the casting speed was slow (~1 inch per second) and the billet had a large mass. The assumption was proven wrong. The billet would change in both its center position, as well as its “swinging” amplitude.

Through out the testing period, patches were added to the system (Task E) to cope with various issues such that the Qualifier could demonstrate its capability. The Qualifier was able to clearly image the billet surface. Both artificially induced and naturally occurred surface anomalies were successfully identified. The issue at this stage was the limited opportunity to verify the naturally occurred surface anomalies. There existed features that even the veterans in the hosting mill could not comment immediately. The verification on the impact of those features to the subsequent rolling processes was difficult in the hosting mill as the mill was practicing direct charge. Nevertheless, images of these features have resulted in strong interest from the collaborating mill that future steps are planned for a permanent installation.

With the gained knowledge, OGT believes that it can now provide a much more adequate design that can be commercially used in the continuous casters. The new design, which is being implemented, will factor in the lessons learned with several temporary patches now integrated into the design. The prototype was removed from the test site in February 2007. The overhaul is on going with a re-delivery scheduled in May 2007.



Condition after Tests, external (left) and internal (right). Components, particularly the exterior, showing effects of harsh environment.



System in work for re-delivery (picture taken in April 2007).

4. Conclusions and recommendations for future work

Results of this project reveal that:

- (1) It is technologically feasible to have a Hot Billet Surface Qualifier for in-line applications in continuous casting operations. The challenges experienced in this project could be overcome with various measures. Access to the hot billet surface, as cast, is no longer impractical.
- (2) The inspection result is of value to the target industry. Despite the difficulty in verification, images of the cast billet surface inside the caster opened the eyes of melting shop veterans. The interest is shown by the facts that (a) the collaborating mill is willing to take the re-delivery, (b) a commercial order was received from another mill for billet inspection, and (c) an invitation from a 3rd mill to start a project for “Slab Surface Qualifier”. Slabs are produced in a similar process (continuous casting) with a different shape or aspect ratio.

Future work includes:

- (1) Revise the design based on the lessons learned and confirm its performance with the re-delivery.
- (2) Document success stories with the hosting mill and the first customers.
- (3) Expand into “Slab Surface Qualifier” with all the experience learned in this project.

Appendix A

Final Task Schedule

Final Task Schedule

Task Number	Task Description	Task Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
1	Design the Qualifier	01/31/06	10/31/05		100%	Completed
2	Implement the Qualifier	05/31/06	01/31/06		100%	Completed
3	Install the Qualifier	06/30/06	06/30/06		100%	Completed
4	Preliminary Test	09/30/06	10/31/06		100%	Completed
5	Refine and Retest	03/31/07	3/31/07		100%	Completed
6	Project Management	03/31/07	3/31/07		100%	Completed

Appendix B

Final Spending Schedule

FINAL SPENDING SCHEDULE

Project Period: 08/01/2005 to 03/31/2007

Task	Approved Budget	Final Project Expenditures
Task 1 Design the Qualifier	71,667	129,017
Task 2 Implement the Qualifier	78,668	122,097
Task 3 Install the Qualifier	120,167	123,976
Task 4 Preliminary Test	192,500	280,770
Task 5 Refine and Retest	257,000	98,102
Task 6 Project Management	18,258	17,144
Total	738,260	771,106
DOE Share	250,000	250,000
Cost Share	488,260	521,106

Appendix C

Final Cost Share Contributions

Final Cost Share Contributions

Funding Source	Approved Cost Share		Final Contributions	
	Cash	In-Kind	Cash	In-Kind
OG Technologies	3,260	75,000	20,273	70,833
Industrial Partner	10,000	400,000	10,000	420,000
Total				
Cumulative Cost Share Contributions				521,106

Appendix D

Energy Savings Metrics

The following analysis is based on a mill similar to the one operated by the collaborating industrial partner.

Annual production volume: 600,000 tons

The comparison is based on the practice currently in use and the practice to be enabled by the proposed technology.

The expected energy savings per mill is 249,000 MMBTU per unit.

One Unit of Proposed Technology:

The proposed technology can be used to enable a new practice. This would result in consumption of 501,000 MMBTU per year in the rolling operation (per rolling mill).

One Unit of Current Technology:

The current practice at the collaborating industrial partner is consuming about 750,000 MMBTU per year in the rolling operation (per rolling mill).

Discussion of Energy Savings:

The energy savings are theoretically derived based on the actual mill operations and the expected benefits from the experimental results of this project. Energy source depends on different mills. Some mill have electrical furnaces and some have gas furnaces. Typically, it would be a combination.

Energy Savings Metrics

Type of Energy Used	A	B	C=A-B	D	E=CxD
	Current Technology (Btu / yr / unit)	Proposed Technology (Btu / yr / unit)	Energy Savings (Btu / yr / unit)	Estimated Number of Units in U.S. by 2010 (units)	Energy Savings by 2010 (Btu / yr)
Oil / Gasoline					
Natural Gas					
Coal					
Electricity (@ 10,500 Btu / kWh)					
Other Energy 1 (Explain)	750,000 MMBTU	501,000 MMBTU	249,000 MMBTU	3	747,000 MMBTU
Other Energy 2 (Explain)					
Other Energy ...n (Explain)					
Total Per Unit	750,000 MMBTU	501,000 MMBTU	249,000 MMBTU	3	747,000 MMBTU